GUIDANCE RELATED TO BYCATCH AND DISCARDS IN CANADIAN COMMERCIAL FISHERIES

Figure 1: Map of the Fisheries and Ocean Canada (DFO) six administrative regions.

Context

Canada has committed under the United Nations General Assembly and the Convention on Biological Diversity to implement conservation and management measures to ensure sustainably managed fish stocks. Aligned with its international commitments, Canada is domestically implementing its Sustainable Fisheries Framework (SFF). A key component of the SFF is the Policy Framework on Managing Bycatch and Discards (in development) which aims to ensure that Canadian fisheries are managed in a manner that supports the sustainable harvesting of aquatic species.

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat (CSAS) national science advisory meeting of March 5-7, 2012 to develop guidance related to bycatch and discards in Canadian commercial fisheries. Additional publications from this process will be posted as they become available on the DFO CSAS website at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- Canada is committed domestically and internationally to implementing conservation and management measures to address bycatch and discards.

Canada

- This scientific advice refers to bycatch species for which information on their biology, distribution, or status is limited, and/or there is a lack of formal abundance estimates.
- Compared to targeted species there will usually be less complete data on bycatch and less knowledge of the population dynamics and demographic rates of bycatch species. Nonetheless, there are actions and analyses that can be undertaken where potential impacts have been identified, as long as those actions and analyses are ecologically appropriate and based on reliable information.
- A variety of strategies and measures are available to managers to ensure the risks associated with bycatch are managed effectively; examples of such strategies and measures are provided in this report.
- Direct estimates of bycatch obtained from complete monitoring programs that reliably reflect the conditions in the fishery are highly desirable. However, complete monitoring may not be possible and the allocation of monitoring resources in these situations should fully consider the risks of fisheries causing serious harm to the bycatch species.
- Benchmarks for bycatch species are used to evaluate whether or not bycatch rates and magnitudes are low enough to be sustainable and avoid serious harm. There is no single best method and using a diversity of approaches is encouraged.
- Natural mortality (*M*) is a key parameter in developing benchmarks for management of bycatch and there are many ways to approximate it with limited information. Approaches to calculate *M* and how to use it in evaluations of bycatch sustainability are provided in this report.
- Under appropriate circumstances, discards and processing waste have the potential to be rationally utilised as a source of raw material in the production of fishmeal and fish oil for aquaculture or other value-added products. To make rational use of Canadian fisheries discards, feed component material must be fresh (i.e. processed close to where it is landed) and of suitable nutrient composition. Given these constraints, the potential opportunities for discard utilisation appear to be limited and should be evaluated on a case-by-case basis.

BACKGROUND

Endorsed by Canada, the United Nations General Assembly (UNGA) approved *Resolution 64/72* on *Sustainable Fisheries* in September 2009. The *Resolution* calls on States and Regional Fisheries Management Organisations and Arrangements (RFMO/A) to apply the precautionary and ecosystem approaches in adopting and implementing conservation and management measures to address bycatch, pollution, over-fishing, and to protect habitats of specific concern.

Coordinated by the *Food and Agriculture Organisation*'s (FAO) *Committee on Fisheries* (COFI), the *International Guidelines on Bycatch Management and Reduction of Discards* were developed to assist States and RFMO/As in implementing the *Resolution* and an ecosystem approach to fisheries through effective management of bycatch and reduction of discards. The FAO *Bycatch Guidelines* can be found at: http://www.fao.org/cofi/cofi2011/en/.

The FAO *Bycatch Guidelines* are voluntary and indicate that States should establish and implement national policies for the effective management of bycatch and reduction of discards based on the application of the ecosystem approach to fisheries and should give consideration to all significant sources of fishing mortality. In addition to efforts to reduce bycatch, the

Guidelines also encourage efforts to ensure rational utilization of the remaining bycatch and discards that would otherwise be wasted. One possible option for the rational utilization of bycatch and discards may be its incorporation into the production of fishmeal and fish oil for aquaculture feed.

Endorsed by Canada and similar to the guidance of the FAO, Aichi Biodiversity Target #6 of the *Convention on Biological Diversity* (CBD) is focused on the sustainable management and harvest of all fish and invertebrate stocks through the application of ecosystem-based approaches, including ensuring that the impacts of fisheries on stocks, species, and ecosystems are within safe ecological limits. The Aichi Targets of the CBD can be found at: http://www.cbd.int/sp/targets/.

In alignment with its international commitments, Fisheries and Oceans Canada (DFO) is domestically implementing the Sustainable Fisheries Framework (SFF) which aims to ensure that fisheries are environmentally sustainable while supporting economic prosperity. A key component of the SFF is its *Policy Framework on Managing Bycatch and Discards* (which is currently under development and referred to hereafter as "the *Bycatch Policy*") that aims to ensure that Canadian fisheries are managed in a manner that supports the sustainable harvesting of aquatic species by: 1) minimising the risk of fisheries causing serious or irreversible harm to bycatch and discard species; and 2) accounting for total catch, including bycatch and discards.

ANALYSIS

Scope of the Advice

The *Bycatch Policy* applies to retained and discarded bycatch. It describes these categories as:

a) Any retained species or specimens that the fisher was not licensed to direct for but is required or permitted to retain;

b) All discards, including catch released from gear and entanglements, whether alive, injured or dead, and whether of the target species or the non-target species.

This scientific advice refers to bycatch species for which information on their biology, distribution, or status is limited, and/or for which there are no formal abundance estimates. These information gaps result in a lesser understanding about the magnitude of bycatch mortality or whether it is sustainable.

This scientific advice does not refer to bycatch species for which there may already be sufficient information to assess stock status or to develop precautionary reference points, and/or which are managed through Integrated Fisheries Management Plans (IFMP). According to the *Bycatch Policy* and the *Fishery Decision-Making Framework Incorporating the Precautionary Approach (PA Framework Policy)*[1], such catches should be fully accounted for and be included in the corresponding target species stock assessment. In many fisheries, however, practices for recording and assessing bycatch need to be improved with regard to stocks and species managed under IFMPs for other fisheries.

[1] Proceedings of the National Peer Review Meeting on the Development of Technical Guidelines for the Provision of Scientific Advice on the Various Elements of Fisheries and Oceans Canada Precautionary Approach Framework; February 28 to March 1, 2012.

General Considerations for a Framework for Managing Bycatch and Discards

Strategies and Measures to Manage Bycatch

Fully achieving the objectives of the *Bycatch Policy* will require varying degrees of change to how information about catches in fisheries is collected and analysed. Currently some fisheries are already devoting substantial attention to managing, and as appropriate, reducing bycatch (e.g. mandatory use of Nordmore grates in certain shrimp fisheries), whereas in other fisheries less is being done with regard to bycatch. Regardless of history, the *Bycatch Policy* will require a systematic examination of bycatch in all Canadian fisheries. It is necessary to consider the catch of a species in all fisheries and across its range. The former is a reasonable goal of Canadian fisheries; the latter is sometimes only achievable with international cooperation given the trans-boundary or highly migratory nature of some species.

In cases where the information indicates that there may be bycatch issues in a fishery, a variety of strategies and measures are available to managers to ensure the risks associated with bycatch are managed effectively such as:

- Gear substitutions and gear modifications to improve selectivity;
- Spatial and/or temporal closures to reduce encounter rates;
- Harvesting caps, market incentives, or other ways to limit total bycatch of particular species or overall;
- Operational protocols to increase the likelihood of successful live release (if unavoidable bycatch is returned to the sea); and/or
- Actively managing the harvest of the population previously considered as bycatch, so it becomes part of a sustainably managed multispecies (or even directed) fishery.

All these options should be considered in each case where bycatch is identified as an issue. This guidance document does not address how such considerations should proceed nor is a detailed review of opportunities for, and anticipated efficacy of, mitigation measures presented. Rather, it focuses on the science activities needed to clarify if and how large an issue bycatch may be in a particular fishery, through guidance on reliably measuring bycatch and on how to assess its sustainability.

Evaluating Bycatch

Evaluation of bycatch relative to the *Bycatch Policy* will require the identification of benchmarks for sustainability, which may include or be broader than reference points in the Precautionary Approach Framework (DFO, 2012). Although DFO policies do not define sustainability, the SFF does highlight that "sustainability" has ecological and socio-economic components; however, it is predominantly the ecological component that is relevant to bycatch. Where there are economic objectives set for the fishery, they would be outside the scope of this advice and benchmarks for their management would come from the IFMP for that species/stock. Social objectives of bycatch species would be linked to other values (e.g. existence, cultural, spiritual, etc.) of the species, and delivered either through achievement of ecological objectives or supersede anything in this advice. In DFO policies, ecological sustainability is typically interpreted to mean there is a low risk of serious harm to the population, where serious harm is interpreted as impaired productivity.

An evaluation of bycatch will usually include at least two parts: 1) identifying life history metrics that reflect species productivity which can inform setting benchmarks; and 2) models to determine where the level of bycatch is relative to those benchmarks. Compared to targeted species there will usually be less complete data on bycatch and less knowledge of the population dynamics and demographic rates of the bycatch species. Therefore, these models and metrics will often not be as sophisticated or mathematically powerful as those used in the management of directed fisheries. Nonetheless, there are many sound and useful analyses that can be done, even with simple metrics and models, as long as they are ecologically appropriate and based on reliable information.

At a coarse level the *Bycatch Policy* requires two primary tasks: 1) the documentation of the composition and magnitude of bycatch in all fisheries; and 2) the evaluation of whether or not their nature and scale pose concerns for sustainability of the population. The section of this report on data and monitoring will address the first task while the section on analytical methods will address the second task. Progress towards completing these two tasks will identify where there are potential problems that may need to be addressed through appropriate combinations of the aforementioned strategies and measures (see section titled "Strategies and measures to manage bycatch" for more details).

The evaluation process is expected to identify bycatch issues in some fisheries. A prioritisation process will be needed to decide where to target resources for a more detailed investigation of the issues and where managers should focus their actions. This advice does not review prioritization methods in detail, but notes several sound approaches are available (Pardo et al, 2012). These approaches appropriately consider the tractability of management interventions to correct problems and the urgency of addressing the issue before serious harm occurs to the population or ecosystem.

It is also expected that in some cases, evaluation of bycatch levels relative to their benchmarks will identify potential for increases of bycatch of species for which there may or may not be a market. In such cases there are both positive and negative considerations to allowing such expansion of bycatch to occur. Positive considerations include opportunities for increased benefits from the fisheries, often within existing fishing effort and management plans or through the staged development of new fisheries. Negative considerations include potential for increased impact of fisheries on the ecosystem and additional challenges to the management of the fishery. For example, redefinition of scope and coverage of plans which may create overlaps in application of different plans.

It may be appropriate to consider such expansions under new and expanding fisheries policies. However, this may be inappropriate in cases where a fishery is long-standing and the bycatch comprises a small part of the total catch; such choices may not be simple. In all cases where the evaluation identifies scope for the expansion to occur, the available and appropriate management options should be considered.

Quantification of Bycatch and Bycatch Mortality

Data Requirements

Specific data are required to determine the amount and nature of bycatch whilst other information can provide added value to address specific objectives, such as determining sustainable mortality limits. This information includes:

1. Bycatch species identification to the lowest taxonomic level possible;

2. Quantity of bycatch (numbers and weight); sub-sampling may be required to determine this;
3. Geographic location of the catch;
4. Type of gear, length and duration of sets;
5. Time and date of capture;
6. Temperature and depth information, where available;
7. Demographic composition of bycatch including (in order of priority),
    - Individual length,
    - Individual weight,
    - Age information (where appropriate and possible),
    - Sex and maturity (where appropriate and possible); and
8. Frozen samples, photographs, and/or genetic samples may be required to confirm identification or for gathering demographic information.

The scope for more detailed analyses will increase with the amount of information available. While it is desirable to have this breadth of information, there are many operational and budgetary constraints that may affect the feasibility to collect it, some of which are outlined in the section on monitoring below.

Monitoring Programs

a) Census

Independent at-sea observation programs that include 100% coverage of a fishery provide a direct census of bycatch and represent an ideal monitoring approach. Alternatively, mandatory retention of all catch with full dockside monitoring could provide equivalent information if supported by appropriate at sea observation and enforcement. The main constraints on 100% at-sea coverage are the increased costs to industry and the feasibility of implementing this level of coverage on small operators. The main constraints on mandatory retention are enforceability, the cost to industry to retaining low value catch, and the conservation impacts of retaining organisms if they would have survived if returned to the water.

Many monitoring programs fall short of the ideal of complete coverage and therefore must be carefully designed to provide maximum value. The time, funding, and availability of monitoring may be limited and usually must meet several objectives, thus the allocation of resources for monitoring should take full account of assessments of the risks of causing serious harm to the bycatch species.

b) Estimation of bycatch

It is highly desirable to have direct estimates of bycatch obtained from monitoring programs. To be useful, monitoring programs for bycatch need to provide data that reliably reflect conditions in the fishery or the nature and magnitude of biases in the data need to be understood. Monitoring programs could include independent at-sea observation (fishery observers or video monitoring), fish harvester logbooks, surveillance by conservation officers, vessel monitoring systems, sighting/stranding networks, and dockside monitoring. There is a continuum in accuracy and precision of bycatch estimates across monitoring methods. Well-structured government or third-party at-sea observation programs with partial coverage are generally

regarded as proving the most reliable estimates of bycatch, while data from non-validated logbook programs are generally regarded as being much less reliable. Where monitoring coverage is only partial, ancillary information (e.g. target species catch, fishing effort) may be required to scale up monitoring observations to the level of the fishery, underscoring the need for maintaining high quality fishery statistics.

A low level of monitoring may not properly characterize the scale and pattern of the impacts, and precision of estimates will generally be low if the bycatch of particular species has been observed to be clustered in space and time and may not be evenly distributed throughout a fishery. In addition, if the results of the monitoring program are to be extrapolated to the full fishery, the design and implementation of the monitoring program must be appropriate and include representative sampling of the fishery. The potential for an "observer effect" (i.e. fish harvesters operating differently in the presence of onboard monitoring) should be considered when planning monitoring programs and when using the information from them. The validity of assumptions underlying a monitoring program should also be regularly assessed.

In addition to having representative samples from the fishery, reported incidentally-captured species need to have been properly identified. Therefore, adequate training of the people reporting bycatch and/or effective procedures to validate species identification should be in place. Where accurate species identification is not possible or is questionable in retrospect, habitat models could be used to estimate the species composition of bycatch where these models have been developed and validated.

There may be cases where there is good reason to believe that a species is both available (i.e. present in the area) and vulnerable to a fishing gear, yet no records appear in the bycatch data; such situations should be priorities for further investigation.

Factors affecting bycatch mortality

Information on the mortality rate is required to establish the sustainability of fishing mortality for discarded marine taxa. Furthermore, understanding the factors affecting the likelihood that discarded fish will die can contribute to better management of resources by enhancing the potential for successful live release.

Formal estimates of capture and discard mortality rate that accurately reflect conditions in fisheries are expensive and time consuming to obtain, and are therefore available for a limited number of species captured in a limited number of fisheries. When these are not available, reliable proxies can be used to evaluate capture and discard mortality risk for individuals. For example, semi-quantitative measures of individual fish vitality or physical condition, obtained by at-sea observers aboard commercial fishing vessels just prior to discarding, relate well to eventual mortality. Where these are not directly available, values can be predicted using empirical models based on factors shown to affect vitality and therefore mortality.

Factors affecting capture and discard mortality can be divided into technical factors (e.g. gear, catch handling practices), environmental factors associated with the fishing activity (e.g. depth of capture, water and air temperatures), biological factors (e.g. species effects, body size), and ecosystem factors (e.g. increased susceptibility to post-release predation). Of these, the gear type used, the handling techniques, and amount of time that bycatch spend on deck prior to discarding are strong contributors to mortality. For example, it has been shown that rapidly discarded line-caught groundfish appear to have higher survival potential compared to those caught in mobile gear fisheries and exposed to extended periods of time on deck. Likewise, there exists a strong inverse relationship between organism size and mortality rate both within and among species. Certain groups of species possess combinations of traits that result in

almost complete mortality when captured and handled, while others are robust to very long periods of exposure.

Analytical Methods for Determining Sustainability of Bycatch

General Approach

Benchmarks for bycatch species are used to evaluate whether or not bycatch rates and magnitudes are low enough to be sustainable and avoid serious harm. This is a simpler evaluation than using reference points for target species in directed fisheries, where the management task is to keep harvests high enough to achieve social and economic objectives without placing the stock at unacceptable risk of serious harm. For the simpler bycatch evaluations, qualitative advice may often be sufficient, and simple population models can contribute to developing benchmarks for managing bycatch.

As with the Upper Stock Reference Point in the *Precautionary Approach Framework Policy*, benchmarks for bycatch management should provide early warnings of potential bycatch issues, not just warnings when serious harm to bycatch species is imminent. This makes the analyses of risks and probabilities of bycatch impacts focus on the tails of the probability distributions, whereas for target species both the center (targets) and tails (limits) are important.

A variety of methods are available for setting benchmarks for evaluating the sustainability of bycatch depending on the type and quantity of information available. A logical flowchart for selecting appropriate methods is provided in Figure 2.

As an initial step, best practice would apply a diversity of appropriate approaches to estimate natural mortality (*M*) rather than only one method. A selection of minimum value, a range, or a distribution of potential estimates of *M* could be used as sources of benchmarks to manage bycatch for species where limited information is available for its assessment. Using a diversity of methods would also allow uncertainty in *M* to be taken into account particularly in data poor simulations. The iterative approach outlined by Quiroz et al. (2010) for propagating uncertainty in the estimation of *M* is recommended when there is sufficient information for the method to be used (e.g. estimates of key life history parameters from several related species or stocks). If this is not possible, then either a range of estimates of *M*, or a precautionary estimate of *M* (i.e. lowest value obtained from a number of methods) should be taken. The list of methods that can be used to estimate *M* is not exhaustive (Table 1). All of these methods require minimal data and all were accepted at the present science advisory process.

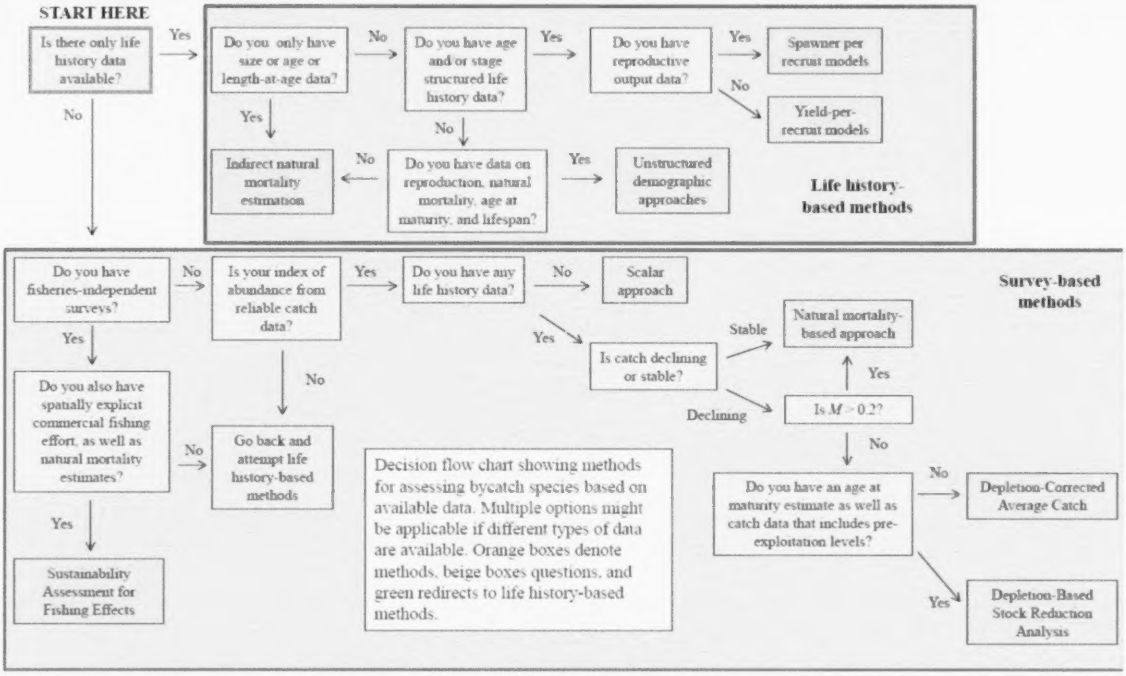

Figure 2. A decision flow chart showing methods for assessing bycatch species based on available data.

Indirect Methods of Estimating Natural Mortality (M)

Indirect methods for estimating natural mortality (*M*) are based on the relationship amongst life history traits which are hypothesized from life history theory and can be used in situations where only life history information is available. A summary of the methods considered appropriate for the indirect estimation of *M* is provided in Table 1. In the absence of age information, the crudest measure of natural mortality is derived from weight (or indirectly from length), for which the Lorenzen (1996) and Peterson and Wroblewski (1984) methods can be used. These methods are based on general trends and can result in highly inaccurate estimates of natural mortality and over-estimate *M*, particularly in long-lived, slow-growing species, such as Pacific Rockfish (*Sebastes* spp.) or elasmobranchs. Given this potential bias could place the stock at risk, this method should not be the only information used to provide estimates of *M* for the purpose of managing bycatch.

When only maximum age (lifespan) is known, average natural mortality for a species can be estimated using the Hewitt and Hoenig (2005) and Hoenig (1983) methods. If only age at maturity is known, then *M* can be estimated using the Jensen (1996) method. However, if there is information on length-at-age, and thus von Bertalanffy growth parameters are available, four methods are suggested. For an average (size-independent) estimate of *M*, the Pauly (1980) method can be used, which also requires mean water temperature from where the species is present which is easily obtainable from meteorological databases. The Gislason et al. (2010) and Charnov et al. (2012) methods also use von Bertalanffy growth parameters and provide length-specific natural mortality for a given species, while Chen and Watanabe (1989) provide an age-specific estimate using the same input parameters.

Table 1. Summary of methods that are considered appropriate for the indirect estimation of natural mortality (M).

Method	Minimum Data Requirements	Size Specific?
Peterson and Wroblewski (1984)	weight	YES
Lorenzen (1996)	weight	YES
Hewitt and Hoenig (2005	maximum age	NO
Hoenig (1983)	maximum age	NO
Jensen (1996)	age at maturity	NO
Pauly (1980)	von Bertalanffy growth parameters and mean water temperature	NO
Chen & Watanabe (1989)	von Bertalanffy growth parameters and length	YES
Gislason et al (2010)	von Bertalanffy growth parameters and length	YES
Chamov et al. (2012)	von Bertalanffy growth parameters and length	YES

Direct Methods of Estimating Natural Mortality (M)

When size- or age-specific catch data (in abundance/numbers) are available, total mortality (*Z*) can be estimated by means of catch curve analyses or year-class curves. Catch curve analyses are appropriate when only one or few years of catch data are available, but assume constant recruitment between years, and constant mortalities and catchability between size or age classes analyzed. Year-class curves require multiple years of age-specific data for which individual cohorts can be followed. This model assumes constant mortality and catchability between age classes, but does not require uniform recruitment, and can be applied to species which have highly variable recruitment events (e.g. Pacific Rockfishes). If catch data are available for multiple years where fishing effort has varied considerably and if the average catchability to the fishery can be assumed to be approximately constant over the years, total mortality can be partitioned and *M* can be directly calculated using the Sustainability Assessment for Fishing Effects (SAFE) method (Zhou and Griffiths, 2008; Zhou et al., 2009).

Rules for Deriving Harvesting Advice from Estimates of Natural Mortality (M)

When it is only possible to estimate *M* for a bycatch species and no other parameters, the Scalar approach can be used (Berkson et al., 2011). Advice can be based on contrasting the realized fishing mortality rate (*F*) of the target species against a proportion of the natural mortality (*M*) of the bycatch species, which is a proxy for the sustainable fishing mortality a species can sustain. In data poor circumstances, $F = M$ might not be considered precautionary, therefore $F = 0.8\ M$ for teleosts and $F = 0.4\ M$ for elasmobranches can be considered a prudent approach (Shijie Zhou, Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Marine and Atmospheric Research (CMAR) Division, Dutton Park, unpublished data).

Using Estimates of Natural Mortality (M) to Evaluate Bycatch Sustainability

There are a series of steps to take when approaching the problem of going from estimates of *M* to providing benchmarks for managing bycatch. The answers to several of the questions below assume some population estimate and/or population model is available for the species. In many cases it will be possible to develop at least simple population models from time-series of catch data, from monitoring bycatch in the fishery, survey time-series of abundance estimates, or many other combinations of sources. In some cases, even quite simple population models (i.e. without time-series information) can contribute to developing more robust benchmarks for

managing bycatch. Even without a population model based on time-series information, methods for using current (or recent) survey data and/or catch data to provide a minimum population estimate are summarized in DFO (2012).

At an early stage in the sustainability assessment, and especially if data-poor species appear to be approaching critical or concerning levels, data should be gathered to allow the application of more complex models. Some simple methods, such as ageing 100 individuals from the bycatch, may provide sufficient information to support improved estimates.

To estimate *M*, either for individual species or for assemblages, the following questions should be addressed:

1. With *M* being used as an index of productivity, species with higher *M* are likely to be more productive and hence able to sustain somewhat higher exploitation rates. Therefore, is the *M* of the species being examined higher than the *M* of the target species of the fishery? If so, there is likely limited justification for immediate concern with the level of bycatch, unless the bycatch species are known to be both rare and have high catchability to the gear.
2. Does the fishery only occur in part of the bycatch species' range? If so, then one should review what is known about habitat preferences, aggregation behaviour, mobility of the bycatch species, spatial management measures, and other fishery or species-specific factors. It may be justified to consider the level of concern to be low when a substantial portion of the bycatch species is not exposed to fishing mortality.
3. Trends in post-recruitment abundance can provide an indication about whether present bycatch levels might be impairing the productivity of the population. To the extent that the trends are considered reliable, the following guidelines apply:
    a) Increasing trends: Do any indicators (e.g. surveys or catch-per-unit-effort) show that the post-recruitment abundance of the bycatch species population is increasing? These trends should always be reviewed relative to possible changes in the fishery, markets, survey design, or other factors that may bias the indicator. If the trend shows an increase, then there is likely limited justification for concern with the level of bycatch.
    b) Stable trends: Do any indicators show that the post-recruit abundance of the bycatch species is remaining constant (or relatively constant) or if the data do not have sufficient information to evaluate a trend? If yes, then it is appropriate to conduct additional analyses to determine if the population is already low enough to have suffered impaired productivity, or otherwise not sustain even low rates of bycatch.
    c) Decreasing trends: Is the post-recruit abundance of the bycatch species population decreasing? If so, a more detailed population assessment for the bycatch species should be made a high priority.

The next step is to determine the level of analysis required based on the answers provided to the above questions. Note that it is important to consider the entire area from which the bycatch species is taken and this may require integration of information from different fisheries.

For a species with a moderate level of concern (e.g. #3b - when the abundance is stable) information from a limited time period can be used to draw a conclusion by comparing the tail of the probability distribution of abundance to the benchmark of sustainable bycatch levels. A

method known as the Depletion-Corrected Average Catch (DCAC) method (MacCall, 2009; NOAA, 2011) is useful for this kind of assessment.

For cases when abundance is declining or is remaining constant at a low level (#3b, 3c),time series of at least two of the following three data types are required to construct an appropriate model: total bycatch numbers caught, fishing effort, and abundance of the bycatch species. Catch reconstructions can be based on educated opinion, ratios to target catch, etc. and need not be very precise. Effort series can be taken from nominal effort (e.g. boat days or trawl hours) in the target fisheries, or from stock assessments of the target fisheries. In the latter case target fisheries can be treated as an index of nominal effort for the bycatch. Time-series of abundance are least likely to be available, but they can be much shorter in length than for full analytical stock assessments and still be useful. Simple models that require three to five years of data can be used, even when augmented by more complicated models requiring longer data series. For example, An Index Method (AIM) is a good model that can be used to assess current conditions and to conclude whether the allowable bycatch is sustainable (NOAA, 2011). As well, short time-series applications of Schaefer models can be used to determine whether the stock is above or below maximum net productivity level (MNPL) (Wade and Angliss, 1997; Wade, 1998; NMFS, 2005).

Only when risk evaluations or the aforementioned modelling suggests that the current level of bycatch may be of concern is there a need to apply more complicated models, such as Depletion-Based Stock Reduction Analysis (DBSRA) and its family (Dick et al, 2011). Ideally, a large number of alternate realisations of a model would be run, based on probability distributions of model parameters. These realizations can be sorted according to their likelihood, producing a Bayesian posterior distribution, and used to assess the likelihood of further declines in the bycatch species under current and alternative fishing scenarios. These scenarios may include use of various measures to mitigate the bycatch, where the measures are considered feasible for the fishery. Another possible model is the Catch-Free Model described in Porch et al. (2006).

Quantification and Potential Utilisation of Discards from Canadian Marine Commercial Fisheries

Quantification of Discards and Processing Waste

In 2009, Canada's capture fisheries landed ~ 914,000 t of fish and shellfish and estimates indicate that a minimum of 38,000 t (~ 4% of total landings) might have been discarded (Chadwick, 2012). An upper estimate of discards is more uncertain but may be as large as 96,000 t (~ 10% of landings) or larger. Approximately 85% of the minimum discard estimate came from dredge fisheries for scallop and surf clam, shrimp trawls, groundfish trawls and large pelagic long-lines. Approximately 10,000 t of these discards came from British Columbia groundfish fisheries, which have 100% at-sea monitoring. Large vessel shrimp fisheries in Shrimp Fishing Areas (SFA) # 2 to 7 and the groundfish fisheries in part of the eastern Arctic also have full observer coverage and provide reliable discard estimates. In all other Canadian marine fisheries there was low confidence in the discard estimates because of low levels or complete absence of at-sea monitoring.

The aforementioned discards were composed of a mixture of demersal fish, crustaceans, molluscs, echinoderms, and sharks, which is not normally the source material for aquaculture feed. Currently, the ingredients of marine origin in aquaculture feed are comprised almost entirely of small pelagic fish, the majority of which are imported from international sources. In

general, global pelagic fish stocks are fully exploited, making sustainable growth of the finfish aquaculture industry dependent upon finding new sources of fishmeal and fish oil.

Discards and waste from commercial fish processing are about tenfold the minimum estimate of discards from capture fisheries, and provide another potential source of fishmeal and fish oil. However, there are many operational and ecological considerations that require evaluation in order to ensure such initiatives are viable.

Operational and Ecological Considerations in Using Discards and Processing Waste for Aquaculture Feeds

Maximum economic potential for Canada's fisheries resources is a desired outcome of DFO's Fisheries and Aquaculture Management programs. The potential use of bycatch, discards, and processing waste for aquaculture feed are being examined here as this material currently may not be used to its maximum potential. Conceptually, harvest fishery discards provide a source of raw material for producing fishmeal and fish oil for use in manufacturing aquaculture feed. Discards, bycatch, and processing waste in Canadian fisheries currently may not be used to the maximum potential possible and the potential use of discards for aquaculture feed are investigated here. Conceptually, discards in harvest fisheries may represent a useful stream of raw materials to be used in the production of fishmeal and fish oil for use in the manufacture of aquaculture feed. The use of marine mammal, turtle, and seabird bycatch is currently prohibited by policy and regulation and thus are not included in the present analysis.

Industry Considerations

To make rational use of discards, the location and concentration of processing plants are key considerations given the need to maintain product freshness. This is a challenge given the wide geographic range over which fish are landed. Onboard processing is an economically viable option for some fisheries given new modular technology that is capable of processing small quantities of raw material. Another key consideration includes the seasonal availability of nutritionally appropriate bycatch species in quantities sufficient to warrant processing. The composition of the available bycatch is also important (e.g. fish vs. invertebrates; high oil/protein levels vs. low). Identification of potential opportunities is dependent on the accurate estimation of the type and volume of bycatch. Most incidentally caught finfish can be easily processed for fishmeal and oil using traditional processing technology. Nutritional composition of molluscs, crustaceans, and echinoderms are not the same as finfish and so must be evaluated on a case-by-case basis as some sources of raw material have little commercial value.

Constraints on the Rationale Use of Discards and Processing Waste for Aquaculture Feeds

Any consideration of the use of discards or processing waste (from capture fisheries and aquaculture) for aquaculture feed should take into account existing and potential uses, including human consumption, agriculture fertilizer, agriculture feed, pet food, commercial fisheries bait, etc. This includes fully understanding the uses of that biomass, the current economic value of those uses, as well as potential uses that may increase economic value.

Some portion of catch may be "regulatory discards" which are required to be returned to the sea for conservation or allocation reasons. Initiatives to retain such catch should demonstrate the following: a) that the economic benefits from retaining the bycatch outweigh the ecological benefits of returning it to the sea; b) that this practice would not lead to increased targeting of the bycatch species; c) that this practice would not increase risk to the bycatch species population; and d) that an agreement on allocation exists.

The potential positive and negative ecosystem impacts, particularly to food webs, of returning dead discards and processing wastes to the sea should be considered on a case-by-case basis. For example, in some cases this biomass may be enhancing other populations while in others, depending on the ecosystem type and state, this return of biomass may cause detrimental effects (e.g. increased risk of hypoxia, increased populations of scavengers that could pose threats to other species in the ecosystem, etc.).

Sources of Uncertainty

This report provides guidance on estimating bycatch when data are limited. Methodologies to consider uncertainty when estimating parameters such as mortality rates of bycatch species are discussed in the report.

CONCLUSIONS

It is highly desirable to have direct estimates of bycatch obtained from complete monitoring programs that reliably reflect conditions in the fishery. However, there are various factors that may limit the availability of complete monitoring and so the allocation of monitoring resources should fully consider the risks of fisheries causing serious harm to the bycatch species.

Compared to targeted species, there will usually be less complete data on bycatch and less knowledge of the population dynamics and demographic rates of the bycatch species. Therefore, models and metrics for bycatch species will often not be as sophisticated or mathematically powerful as those used in the management of directed fisheries. Nonetheless, there are many sound and useful analyses that can be done, even with simple metrics and models, as long as they are ecologically appropriate and based on reliable information.

Benchmarks for bycatch species are used to evaluate whether or not bycatch rates and magnitudes are low enough to be sustainable and avoid serious harm. This is a simpler evaluation than using reference points for target species in directed fisheries, where the management task is to keep harvests high enough to achieve social and economic objectives without placing the stock at unacceptable risk of serious harm. For the simpler bycatch evaluations, qualitative advice may often be sufficient, and simple population models can contribute to developing benchmarks for managing bycatch.

There is no single best method for estimating benchmarks for management of bycatch, both because of the uncertainties about bycatch levels in specific fisheries and the incomplete knowledge of the population dynamics and demographics of bycatch species. Using a diversity of approaches, rather than using a single estimate of the benchmarks, is encouraged and uncertainty in the benchmarks can contribute to management consistent with a precautionary approach.

Natural mortality (M) is a key parameter in developing benchmarks for management of bycatch, because it can be used as an index of productivity, particularly for stocks that have not been reduced substantially in abundance, and because there are many ways to approximate it with limited information.

Discards and processing waste could be used as a future source of fishmeal and fish oil. However, given the operational and ecological considerations involved in such initiatives there appear to be very limited and local opportunities for this in Canadian marine fisheries. As such, opportunities should be evaluated on a case-by-case basis.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat (CSAS) national science advisory meeting of March 5-7, 2012 to develop guidance related to bycatch and discards in Canadian commercial fisheries. Additional publications from this process will be posted as they become available on the DFO CSAS website at: http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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